Mark schemes

Q1.

(a) Determines s and r in consistent units
OR

Uses A = 2 × parallax angle = $2 \times (1 \div (\frac{79}{3.26}))$
✓

eg for MP1

- *$s = 2 \times 1.5 \times 10^{11}$ m; $r = 79 \times 9.46 \times 10^{15}$ m*
- *$s = 2 \div 2.06 \times 10^{5}$ pc; $r = 79 \div 3.26$ pc*
- *tan (A/2) = orbital radius ÷ distance to star*

with consistent units

$A = 4.0 \times 10^{-7}$ rad = 2.3×10^{-5} degrees

Evidence for MP1 can be seen in the figure.

2.3×10^{-5} degrees CAO ✓

2

(b) Use of $m - M = 5 \log (d/10)$ with two correctly substituted from m, M or d
1✓

If no other mark given, award 1 mark for recognition that 0.40 pc is a lot less than the distance to nearest known star and therefore determination must be incorrect.

For MP2 expect to see

Obtains correct value of m, M or d 2✓

*$d = 2.3$ **pc** OR $m = 9.7$ OR $M = 20.5$*

Alternative for MP1 and MP2

using m, M and d in $m - M = 5 \log (d/10)$ 1✓

seeing -3.2 for LHS and -7.0 for RHS 2✓

Compares **their** value with value given in question 3✓

MP3 and MP4 cannot be awarded without a comparison of the distances.

Makes comment about significance of difference between **their** values related to the distance AND some idea of whether the astronomer's suggestion is valid consistent with their values.4✓

MP4 is for a recognition of the large difference between their calculated value and value given in question eg by proportion, >>, 6 x bigger, significantly bigger etc.

If a difference is calculated in MP3, for MP4 to be awarded the difference must compared to one of the distances.

4

[6]

Q2.

(a) Use of $\lambda_{max}T$ = constant to determine their λ_{max}, their T or their constant✓

Throughout the answer:

Allow 0.47 to 0.49 μm for λ_{max} from the graph

Comparison with $\lambda_{max} = 0.48 \times 10^{-6}$ (m) OR $T = 6.0(4) \times 10^{3}$ (K) OR constant = 0.0029 m K
AND conclusion that the graph is consistent.✓

Allow 6.17×10^{3} to 5.92×10^{3} (K) for their calculated T.

Allow 2.82×10^{-3} to 2.94×10^{-3} (m K) for their calculated constant.

2

(b) Using $P = \sigma AT^4$ to give
$P = 5.67 \times 10^{-8} \times 4\pi \times (9.6 \times 10^{6})^2 \times 6000^4$ ✓

*In MP1 condone **one** error from*

- *missing the 4*
- *missing the π*
- *doubling the radius and using it as r in an area calculation*
- *POT errors*

Condone σ for 5.67×10^{-8}

8.5×10^{22} (W) ✓

*Allow full credit for use of their T from **part (a)***
eg $T = 6.04 \times 10^{3}$ (K) gives 8.75×10^{22} (W)

2

(c) ✓ in top box (white dwarf, F)

1

(d) Shorter wavelengths will have been removed (more)

Allow reverse arguments

OR

star's observed spectrum has lower intensity at shorter wavelengths

OR

(observed) peak of black-body is at a greater value of λ (than shown in Figure 3)/shifted to the right. ✓

($\lambda_{max}T$ = constant,) therefore the (observed/estimated) value of T is lower than the actual T / value of T in **part (a)** ✓

MP2 is contingent on MP1

2

[7]

Q3.

(a) Diagram with 1 AU, 1 pc **and** $\frac{1}{3600}$ ° labelled ✓

*Allow 1 arc second **or** 1" **or** 2.8 x 10^{-4} °*
***or** 4.8 x 10^{-6} rad for angle.*
1 AU can be shown as Sun-Earth distance.
Condone 'au' for 'AU'.
1 pc can be either long side. Condone label d for 1 pc.

1

(b) B ✓

1

(c) evidence of 10^x seen

OR

evidence of 0.11 - (-7.84) seen✓

condone 0.11 + 7.84 provided m-M seen.

d = 390 (pc) ✓

Calculator value is 389.0451

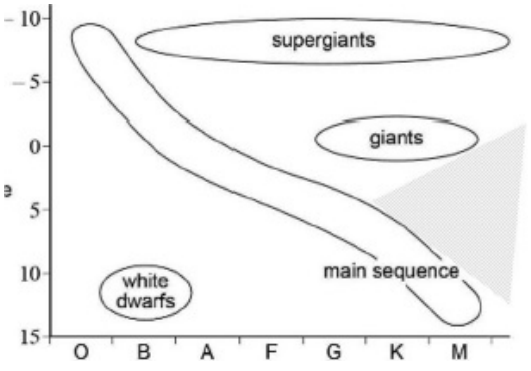
2

(d) Line coming in from the right to mag 5/class G

then to giants and

then to white dwarfs (in that order) ✓

Condone lack of arrow.
The shaded area shows the acceptable region for the initial line (from protostar).



1

[5]

Q4.

(a) (Each step on magnitude scale is 2.51)

(Hence) $2.51^{x} = 40$

$x = \log_{2.51}(40) = 4(.01)$

OR

Adding 6 to their x ✓

(6 + 4 =)10 ✓

Condone trial and error (2.51^1, 2.51^2,...).

Award MAX 1 if no working shown for a bald correct answer.

2

(b) (Collecting power of telescope is)

$\left(\frac{60}{7}\right)^2$ = 73 or 74 (times greater than naked eye) ✓

MP1 can be given for 73 or 74 seen.

Accept $\left(\frac{7}{60}\right)^2$ *= 0.014 for MP1*

73 (or 74) is greater than 40 so the astronomer can see WASP-82. ✓

Allow an ecf in MP2 from '8.6 times greater'

($\frac{60}{7}$ *= 8.6) , with idea that 8.6 is less than 40 and therefore astronomer cannot see Wasp-82.*

Allow ecf in MP2 for an arithmetic error in MP1.

2

(c) Two clear reasons given ✓✓

Correct justification linked to one reason ✓

Reason	Justification
Better/greater quantum efficiency	A greater proportion of (incident) photons are detected
Can expose for long periods / many images can be combined	More light is collected / better image contrast
Can operate remotely	The telescope can be positioned where light pollution/atmospheric absorption is minimised
Idea that it can detect (more) wavelengths beyond the visible	More energy is collected from the star

MAX 3

*If no justification given then **MAX 2**.*

In the first row:

Do not allow 'efficiency' alone.

The reason and justification marks can both be awarded for an answer based on the definition of 'quantum efficiency' e.g.a greater proportion/ percentage of the incident photons are detected (by the CCD).

In the justification condone 'light' for 'photons' and condone 'number' for 'proportion'

Treat 'image processing' as neutral.

Ignore references to resolution.

3

[7]

Q5.

The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria
6	All three areas (as outlined alongside) covered with at least two aspects covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all three areas, with two areas discussed successfully and one area partially.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed successfully and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed successfully, or makes a partial attempt at two areas.
1	One of the three areas covered partially. There are likely to be many errors or omissions.
0	No relevant analysis.

Area 1: Stars compared for colour
M40 B will appear more red than M40 A as it is cooler.
M40 A is an F/G star; M40 B is a K class star Therefore M40 A is white/yellow-white and M40 B is orange
Ignore calculation of λ_{max} unless linked correctly to colour.
Classes are related to colour/temperature

Area 2: Stars compared for brightness
M40 A will appear (~1.5 times) brighter than M40 B, as the apparent magnitude is 0.4 less than that of M40 B.
Difference in magnitude = 0.4
Ratio in brightness = $2.51^{0.4} = 1.5$

Area 3: Distance discussed
Powers compared:
Using $P = \pi A T^4$ gives
For A: $P = 5.67 \times 10^{-8} \times 4\pi \times (6.3 \times 10^9)^2 \times 6000^4 = 3.66 \times 10^{28}$ W
For B: $P = 5.67 \times 10^{-8} \times 4\pi \times (1.1 \times 10^{10})^2 \times 4700^4 = 4.22 \times 10^{28}$ W
As power output of **A** is less than that of **B** but **A** appears brighter, **A** must be closer and therefore they are not a binary.

[6]

Q6.

(a) The minima are caused when one star passes in front of the other. ✓

For mp2 it must be clear that dip size is related to temperature.

1

Deeper minima are caused by the cooler star passing in front of the hotter star. ✓

NB this is NOT related to the diameter of the star.

1

(b) The system is moving towards us AND mention of Doppler/red shift/effect ✓

OR

The system is moving so the light is blue shifted ✓

Condone 'star is, or stars are moving towards us'

1

(c) $\Delta\lambda = \frac{486.498 - 485.672}{2} = 0.413 \text{ nm}$ ✓

$z = \frac{\Delta\lambda}{\lambda} = \frac{0.413}{486.085\checkmark} = 8.50 \times 10^{-4}$

Alternative for mp1 use of average and one of the other values.

For mp2 must see evidence of correct use of average value (NB use of other wavelengths likely to give same answer to 3 sf).

2

$v = zc = 8.50 \times 10^{-4} \times 3.00 \times 10^{8} = 2.55 \times 10^{5} \text{ m s}^{-1} = 255 \text{ km s}^{-1}$ ✓

Average value (486.085)

Final answer must be seen to more than 2sf

For mp3 Allow ecf from mp1 and mp2 if answer is in range 250-260

1

(d) Identifies period (T) is 2.5 days ✓

$$v = \frac{2\pi R}{(their\ value\ of)\ T}$$

$R = \frac{v \times T}{2\pi} = \frac{2.55 \times 10^{5} \times 2.5 \times 24 \times 3600}{2\pi} = 8.76 \times 10^{9} \text{ m}$ ✓

Allow ecf from ***(c)***

1

Use of 250 $km\ s^{-1}$ gives $8.59 \times 10^{9}\ m$ ✓✓

1

(e) hydrogen and helium ✓

1

[9]

Q7.

(a) High power/powerful radio emitter. ✓

Some indication of high power needed.

1

(b) Use of $m - M = 5 \times \log\frac{d}{10}$ ✓

1

$M = m - 5 \times \log\frac{d}{10}$ ✓

$M = 12.8 - 5 \times \log\frac{760 \times 10^6}{10} = -26.6$ ✓

1

(c) Quasar is brighter because more negative abs magnitude. ✓

Difference in absolute magnitudes 26.6 − 22.8 = 3.8 ✓

Brighter by $2.51^{3.8} = 33$ times ✓

Use of -27 (giving 48 times brighter) scores mp2 and mp3

Allow any value of absolute magnitude which rounds to -27.

Use of apparent magnitudes scores no marks.

3

[6]